A Symposium on Cooling Water Intake Technologies to Protect Aquatic Organisms

MAY 6-7, 2003

Hilton Crystal City at National Airport

BIOSKETCHES and ABSTRACTS

Tuesday, May 5
8:00 AM – 9:00 AM

KEYNOTE SPEAKERS

Benjamin Grumbles
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Mr. Benjamin H. Grumbles was appointed Deputy Assistant Administrator for the Office of Water at U.S. EPA in February of 2002. Before coming to EPA, Mr. Grumbles was Deputy Chief of Staff and Environmental Counsel for the House Science Committee since February 2001. Prior to that, he was Senior Counsel for the Water Resources and Environment Subcommittee of the Transportation and Infrastructure Committee. During his 15 years of service on the Transportation and Infrastructure Committee staff, Ben focused on programs and activities of the Environmental Protection Agency, the Army Corps of Engineers, the National Oceanic and Atmospheric Administration, the U.S. Department of Transportation, the Federal Emergency Management Agency, and the Tennessee Valley Authority. He is also an adjunct professor of law at the George Washington University Law School, as well as a member of the faculty advisory board of the Environmental Law and Policy Program at the USDA/Graduate School. He currently teaches courses in water pollution control, the Clean Water Act, and environmental policy. Mr. Grumbles has written numerous articles on water quality, wetlands, water resources management, oil spills, hazardous waste, and environmental policy. His degrees include a B.A., Wake Forest University; J.D., Emory University; and LL.M. in Environmental Law, the George Washington University Law School.

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Mr. Alex Matthiessen is the River's most visible and aggressive advocate. With the help of a team of attorneys and the Pace Environmental Litigation Clinic, he investigates potential threats to the watershed and enforces environmental law in order to safeguard the Hudson River valley and the New York City drinking water supply.

Mr. Matthiessen came to Riverkeeper in 2000 from the U.S. Department of Interior, where he served as Special Assistant to the Deputy Secretary on matters of special importance to Secretary Bruce Babbitt. Matthiessen's primary responsibility was overseeing a government-wide task force to reform the Federal Energy Regulatory Commission's hydropower licensing process. While at the Department of the Interior, Matthiessen also conceived and developed the Green Energy Parks initiative, a joint program of the National Parks Service and the Department of Energy, which promotes clean and sustainable energy use throughout the national park system. For his leadership on the project, Matthiessen received a Presidential Award from the White House. Prior to joining the Department of the Interior, Matthiessen spent a year in Indonesia as a Macroeconomic Policy Analyst for the Harvard Institute for International Development and a summer working at the White House Council on Environmental Quality. In a stint as an independent environmental consultant, Matthiessen wrote foundation grants and authored papers on the potential social and environmental impacts of international trade liberalization. Earlier in his career, he served as the Grassroots Program Director for the Rainforest Action Network in San Francisco, organizing and managing an international network of affiliate activist groups.

Matthiessen earned a Masters of Public Administration from the John F. Kennedy School of Government at Harvard University in 1995 and a Bachelor of Arts, with degrees in Biology and Environmental Studies, from the University of California at Santa Cruz in 1988.

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Dr. Charles Goodman is the Senior Vice President of Research and Environmental Affairs for Southern Company, one of the largest generators of electricity in the United States, serving more than four million customers in the southeastern U.S.

Dr. Goodman joined Southern Company in 1971. He received his B.S. in Mechanical Engineering form the University of Texas at Arlington and his M.S. and Ph.D. degrees in Mechanical Engineering from Tulane University. Dr. Goodman directs the environmental policy, research, and the compliance strategy development program of Southern Company. Reporting to Dr. Goodman are the Environmental Stewardship, Customer Technologies, Power Technologies, Economic Analysis, Environmental Assessment, and the Environmental Compliance Strategies and Permitting departments. Dr. Goodman is a member of the U.S. Environmental Protection Agency Clean Air Act Advisory Committee. He is also a member of Electric Power Research Institute's Research Advisory Committee and chairman of the EPRI Environment Sector Council. In his current role, he is the lead officer for Southern Company's environmental policy, and he oversees the company's research and environmental affairs activities.

Tuesday, May 5
9:00 AM – 10:00 AM

OVERVIEW PRESENTATIONS

An Overview of Fish Protection Technologies and Costs for Cooling Water Intake Structures

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BIOSKETCH
Mr. Ned Taft is President of Alden Research Laboratory. He received his B.S. in Biology from Brown University and his M.S. in Biology from Northeastern University. In addition to his role as President, Mr. Taft is responsible for Alden's environmental services. He has over 30 years experience in developing and testing fish protection technologies for both cooling water and hydroelectric project intakes. He is currently heading the 316(b) team at Alden.

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Mr. Thomas Cook is Director of Environmental Engineering at Alden Research Laboratory. Mr. Cook received his B.S. in Civil Engineering from the University of Vermont. He is responsible for conceptual and detailed design engineering efforts related to fish protection and passage at steam electric, hydroelectric, and water resource projects. He specializes in economic analyses of alternative fish protection and provides the hydraulic, hydrologic, and structural expertise necessary for their installation.

ABSTRACT
The Environmental Protection Agency's proposed § 316(b) Rule requires a thorough understanding of fish protection technologies that can be considered for potential use at cooling water intake structures (CWIS) to address concerns over fish entrainment and impingement. For over thirty years, industry groups and government agencies have been working to develop both biologically and cost-effective technologies. These efforts have led to the development of a suite of technologies that address a wide array of biological, environmental, and engineering characteristics associated with different target species, water body types (*e.g.*, rivers, lakes, estuaries), and physical locations (*e.g.*, offshore, onshore, in-river). Research continues on new technologies, as well as on modifications to, and enhancements of, existing technologies. Within the time available, the following will be presented: (1) available information on permanent installations of fish protection technologies (physical and behavioral) and related research efforts; (2) the current status of available technologies; and (3) ranges of costs based on historical data. Technologies for whose status will be reviewed include: wedgewire screens, modified traveling screens (fine and coarse mesh), aquatic fabric barriers, and barrier nets. The focus will be on those technologies that hold the greatest promise of meeting the national performance standards proposed under EPA's rulemaking.

An Overview of Flow Reduction Technologies for Reducing Aquatic Impacts at Cooling Water Intake Structures

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Mr. Reed Super received his JD and MBA degrees from the University of Virginia. He has practiced environmental law since 1992, and since 1994 has been working on clean water issues with Waterkeeper Alliance programs. Since 2000, Mr. Super has directed Riverkeeper's National Fisheries and Power Plant Program. He is the author with David Gordon of *Minimizing Adverse Environmental Impact: How Murky the Waters*? and teaches Preservation Law as an adjunct professor at Hofstra University School of Law.

ABSTRACT

Power plants and factories withdraw more than 100 trillion gallons per year from U.S. waters for cooling. As a result, hundreds of billions of adult and juvenile fish, eggs, larvae and other aquatic biota are killed as they are sucked through the plants' heat exchangers (entrained) or trapped against intake screens (impinged). Two fundamental methods exist for reducing entrainment and impingement: flow reduction, which reduces the volume and velocity of water withdrawals; and screening, which attempts to screen or divert fish away from the intakes. This paper will present an overview of flow reduction technologies. It will review the most compelling reasons why flow reduction is desirable for reducing aquatic impacts. A variety of flow reduction technologies will be discussed, and the level of flow reduction available from each technology will be assessed. Such technologies include closed-cycle wet cooling, dry cooling, repowering (i.e., adding a combustion turbine to a steam plant), variable speed pumps, changing source water (from surface water to municipal, groundwater or effluent), seasonal outages (as a technology operational measure), and combinations of the above. The paper will assess issues of concern in evaluating flow reduction technologies, such as the extent of reduction in impingement and entrainment obtained as compared with other technologies, the effect on energy generation efficiency (energy penalty), technical feasibility, and costs to plant owners and electricity consumers. Finally, recent examples of the use or proposed use and evaluation of flow reduction technologies at new, existing and replacement power plants will be discussed.

Tuesday, May 5
10:30 AM – 12:00 PM

Session A:
State-Level Issues

Maryland

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Mr. Richard McLean is Senior Administrator and Manager of Nuclear Programs for the Power Plant Research Program of Maryland's Department of Natural Resources. He received his B.S. degree in Biology in 1968 from Pennsylvania State University, and subsequently worked in the monitoring and evaluation of power plant environmental effects with the Academy of Natural Sciences of Philadelphia before joining MDNR. He has been involved in all aspects of ecological impact assessment of power plants, particularly relating to nuclear facilities, for more than 25 years.

ABSTRACT
As an EPA-delegated state, in the late 1970's Maryland developed and enforced regulations regarding cooling water intake structures (CWIS) in accordance with EPA guidance on implementation of Clean Water Act Section 316(b) provided at that time. Maryland regulations establish procedures to determine adverse environmental impacts due to impingement and entrainment relative to determination of best technology available (BTA) for minimizing these impacts. Under the Code of Maryland Regulations (COMAR) at Title 26.08.03.04-05, a CWIS operator is required to determine if the entrainment loss results in a significant adverse environmental impact to a spawning and nursery area of consequence. Relative to impingement, the dollar value of the organisms killed by impingement is to be calculated, and the plant operator is required to implement technologies to reduce impingement only to the extent that the cost does not exceed the total value of lost organisms over a five-year period (in practice, generally five times the value of fish lost to impingement in a single year). Maryland has applied these regulations to all fourteen power plants in the State that operate CWIS, including facilities located on both freshwater and estuarine waters. Over the past 30 years, the Power Plant Research Program participated in and/or conducted studies of a wide range of technologies including, for example, wedgewire screens, modifications to intake structures, dual-flow intake screens, altered plant operations (e.g., screen rotation times) and installation of barrier nets. These evaluations resulted in a range of determinations, from a decision that the existing CWIS was BTA to requiring installation of tested technologies at some facilities (e.g., barrier nets at Chalk Point). Therefore, we believe there is no single technology or suite of technologies that can be applied on a statewide or national basis. However, we believe it is important to have a consistent national process for identifying BTA at the site-specific level.

New York

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Mr. Ed Radle is the now-retired, former Steam-Electric Unit Leader for the New York State Department of Environmental Conservation, Division of Fish, Wildlife, and Marine Resources. Mr. Radle has an Associates Degree in Chemical Engineering from Keystone College in Pennsylvania, a B.S. in Biology from Fairleigh Dickinson U. in New Jersey, and a M.S. in Marine Fisheries from the University of Delaware. Mr. Radle has spent the past 25 years with the NY DEC, initially as an Aquatic and Terrestrial Ecologist, then as the Hudson River Program Coordinator, and finally as the Steam-Electric Unit Leader. The Unit's primary work involves specifying monitoring programs, and where necessary, working with permittees and interested parties to mitigate aquatic impacts at water intakes as part of the state's SPDES permit program.

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Mr. Michael Calaban works as a biologist for the New York State Department of Environmental Conservation (DEC). Mr. Calaban received his B.S. and M.S. in Biology from the State University of New York College at Brockport. After graduation he worked as a technician for an environmental testing laboratory in Hackensack, NJ, and for the Department of Neurology at Albany Medical Center. He has worked for the State of New York for 18 years, for both the Department of Health's Bureau of Toxic Substance Assessment, and the DEC Division's of Permits, and Fish, Wildlife and Marine Resources. For the past 13 years he has worked on energy issues for the Division of Fish, Wildlife and Marine Resources. His work is primarily focused on mitigating adverse aquatic impacts from the operation of large cooling water intake systems.

ABSTRACT

When New York State began issuing SPDES permits, there already existed a great deal of local history with respect to aquatic impacts from cooling water intakes and the steps that should be taken to mitigate these impacts. There was controversy over federal permits granted to construct a large pumped storage hydroelectric facility, and the US EPA had issued permits for 3 large steam-electric stations located on the Hudson River that required retrofitting of cooling towers. The permittees requested a hearing termed the Hudson River Power Case, and several years later an historic, negotiated Settlement Agreement ensued. Within this environment, DEC staff concluded that any mortality at a water intake was adverse; the relevant question was what was a reasonable response to any mortality, given the available technology and its effectiveness, from an agency that represented the interests of all of our citizens, both corporate and private? DEC staff also realized that requiring the best technology available was an empty promise if no one was working to advance the mitigative performance of what was available. Today's presentation is intended to provide an overall view of the program that grew out of these circumstances.

California

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BIOSKETCH

Mr. Wantuck is currently Chief of Fisheries Bioengineering for NOAA Fisheries, Southwest Region of the U.S. Department of Commerce in Santa Rosa, CA. Mr Wantuck was educated at the University of the State of New York and Cornell University, receiving (2) Bachelor of Science degrees and a Masters degree in the fields of Sociology and Government, Environmental Science and Technology, and Aquacultural Engineering. Mr. Wantuck was a former small business owner in the water treatment field- servicing water resource and water quality needs of commercial, residential, and industrial clients. Mr. Wantuck is a U.S. Navy Veteran, who served honorably for 6 years in the Navy Nuclear Propulsion Engineering Program. Mr. Wantuck has more than 20 years experience in various aspects of water resources and hydraulic engineering, as well as natural resource and aquatic species protection.

ABSTRACT

Cooling Water Intake Structures at power plants are required to meet certain standards of fish protection as mandated by the Clean Water Act 316(b) Rule, as well as other regulatory statutes in various areas across the nation. These standards are based on the idea of protecting sensitive fisheries populations, and the ecosystem as a whole, from serious and irreversible decline. Resource Agencies seek to prevent entrainment and impingement of aquatic species at the point of diversion via proven technologies. On the west coast, the conventional method of achieving these goals is through the use of positive barrier fish screens. In recent years, however, a number of new technologies are promoted as a more cost effective means of achieving the required level of fish protection. Recognizing this technology question, NOAA Fisheries Southwest Region has promulgated a set of Agency guidelines entitled: *Experimental Fish Guidance Devices* (1994), to govern the development, implementation, evaluation, and monitoring procedures used to assess the efficacy of any given technology. The American Fisheries Society Bio-Engineering Section has also produced: *Guidelines for Evaluating Fish Passage Technologies* (2000). These two guidance documents will be reviewed.

Tuesday, May 5
1:30 PM – 3:00 PM

Session B:
Flow Reduction

Retrofit of Closed-Cycle Cooling Unit with Specific Mechanical Draft Wet Cooling towers with By-Pass Capability: A Case Study

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Mr. Reed Super received his JD and MBA degrees from the University of Virginia. He has practiced environmental law since 1992, and since 1994 has been working on clean water issues with Waterkeeper Alliance programs. Since 2000, Mr. Super has directed Riverkeeper's National Fisheries and Power Plant Program. He is the author with David Gordon of *Minimizing Adverse Environmental Impact: How Murky the Waters*? and teaches Preservation Law as an adjunct professor at Hofstra University School of Law.

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BIOSKETCH
Mr. John Torgan serves as Narragansett BayKeeper, an advocacy program of Save The Bay, Southeastern New England's largest non-profit environmental group dedicated to protection and restoration of Narragansett Bay. He has been with Save The Bay since 1993. Mr. Torgan holds a B.S. in Environmental Studies/Biology from Union College in NY. He is a master's candidate at the University of Rhode Island Department of Marine Affairs. Before joining Save The Bay, John worked for Ichthyological Associates in NY and Michigan conducting habitat assessments related to power plant permitting. He has served on a number of national committees, mostly related to the environmental aspects of marine transportation, and presently serves on the National Academy of Science/Transportation Research Board committee on Marine Transportation Systems.

ABSTRACT
Direct-cooled, steam-electric power plants can withdraw up to several billion gallons of cooling water per day, resulting in the entrainment of more than a billion fish, eggs and larvae per year, and the discharge of substantial thermal pollution.

Closed-cycle recirculating cooling systems cut cooling water usage by approximately 70-96 percent (depending on the salinity of source waters and local water quality standards) compared to once-through cooling systems, thereby reducing impingement and entrainment and other aquatic impacts by a similar percentage. According to the USEPA, 100 percent of the combined-cycle power plants with a cooling water intake capacity greater than 2 MGD built in the last twenty years and 88 percent of the 2+ MGD coal-fired facilities built in the last 10 years have a closed-cycle recirculating cooling system.

Retrofits of cooling towers on existing facilities are less frequent, but have been completed at a variety of facilities, including a gas-fired plant on a west coast estuary, a nuclear plant on a Great Lake, and coal-fired plants on eastern seaboard rivers. Retrofits are also currently planned at several other US facilities, including

100 percent cooling towers at the McDonough and Yates plants on the Chattahoochee River. Several different retrofit options have been evaluated for some or all of the four units at the Brayton Point Power Station in Somerset, Massachusetts, including unit-specific and/or multi-mode cooling towers.

The paper will focus on the retrofit of mechanical draft wet cooling towers with or without by-pass capability as a case study of one closed-cycle retrofit technology option. It will address environmental advantages and any disadvantages, costs, feasibility and retrofit considerations.

Innovative Cooling Water System for Heat and Flow Reduction at the Brayton Point Power Station

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Dr. Thomas Englert is a partner in Lawler, Matusky & Skelly Engineers and Manager of the Environmental Modeling and Analysis Group. Dr. Englert has a PhD in Chemical Engineering from Princeton University. For the past thirty years he has conducted and supervised modeling studies and data analyses as part of 316 evaluations regarding the effects of power plants operations on fish populations. This has included evaluation of intake effects (impingement and entrainment) as well as the effects of thermal discharges. These evaluations have also addressed the costs and benefits of alternative intake technologies and cooling systems. His current research interests include the effects of the proposed 316(b) regulations for existing facilities on power plant operations.

ABSTRACT

Brayton Point Station, a 1600-megawatt (MW) four-unit fossil fuel electrical generating station located in Somerset, Massachusetts, uses Mount Hope Bay for withdrawal and discharge of condenser cooling and service water. As part of the NPDES permit renewal application and 316(a) and (b) Demonstration, the Station developed an innovative cooling-water system to reduce the amount of flow from and heat discharged to the bay. Referred to as the enhanced multi-mode system (EMM), the new technology includes a 20-cell mechanical-draft counter-flow cooling tower linked to each of the four generating units via a unique piping configuration. The piping permits rapid switching among the four units, thus enabling the capture and removal of heat from the warmest condenser-heated water under any Station operating scenario. Further, the absence of "hard piping" characteristic of conventional closed-cycle systems avoids the need to shut down a generating unit when the cooling tower to which it is piped must be shut down. Compared to current operating conditions, the EMM system would yield a 33% reduction in cooling water withdrawal and heat load. Reductions in entrainment and impingement of fished species and their prey would trim equivalent adult losses by 40 percent. Biothermal effects on a series of life-cycle functions, already negligible under current Station operation, would be reduced further. While significant costs would arise in constructing, operating, and maintaining the EMM system, economic analyses suggest that it represents the most cost-effective technology and the most favorable cost-to-benefit ratio of three alternative cooling-water systems evaluated by the Station. The EMM system is highly specific to Brayton Point Station. Nonetheless, the concept of a dynamically configurable cooling-water system is potentially applicable across a variety of power plant installations.

Design and Performance of Optimized Air-Cooled Condenser at Crockett Cogeneration Plant

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Mr. Bill Powers is the principal of Powers Engineering, an air quality consulting engineering firm established in San Diego in 1994. Mr. Powers has a bachelor's degree in mechanical engineering from Duke University and a master's degree in environmental science from the University of North Carolina – Chapel Hill, and is a registered mechanical engineer in California. His project work focuses on air emission control technology assessments for new power projects and existing industrial sources. Recent projects include: 1) co-authorship of two Electric Power Research Institute gas turbine power plant siting documents, 2) preparation of air permit applications for five 49 MW ultra-low NO_x simple-cycle gas turbine peaking plants in California, 3) development of draft air emission standards for power generation plants, petroleum refineries, and oil production facilities for the Ministry of Energy and Mines in Peru, and 4) evaluation of effectiveness of US-Mexico binational agreement to minimize SO_2 emissions from border copper smelters.

Mr. Powers was the organizer of the Dry Cooling Symposium held in San Diego on May 31 – June 1, 2002. He is also chair of the Border Power Plant Working Group, formed in May 2001 to promote the establishment of a binational sustainable development policy for power plants constructed in the border region. The border region is currently experiencing an unprecedented "boom" in power plant construction. The three primary components of the proposed power plant policy are: 1) "net zero" air emissions, 2) use of dry cooling systems to eliminate cooling tower PM_{10} emissions and conserve water, and 3) use of zero liquid discharge systems.

ABSTRACT

This paper addresses the design and performance of the air-cooled 240 MW Crockett Cogeneration Plant (Crockett Cogen) and "lessons-learned" that could be applicable to larger combined-cycle plants. Crockett Cogen came on-line in 1996 and is located on San Francisco Bay. The plant is composed of a single GE PG7241 FA power block. The power block consists of one GE Frame 7FA gas turbine, one Vogt heat recovery steam generator, 260 MMBtu/hr (LHV) duct firing capacity, and a single steam turbine. The plant is located on a 2.4 acre site between the bay and a sugar processing plant. The air-cooled condenser (ACC) is located on the roof of the powerhouse due to the space restrictions at the site.

The Crockett Cogen ACC design was optimized for height, noise, footprint and performance. The overall height of the powerhouse and ACC is 130 feet. The net height of the ACC from the powerhouse roofline to the top of the ACC is 70 feet. Ultralow noise fans are utilized due to the proximity of a residential neighborhood (< 300 ft. from ACC). A significant portion of plant steam production is typically used by the sugar processing plant. However, the ACC is designed to provide sufficient cooling to achieve a steam turbine power output of ~80 MW at the maximum site temperature of 96 ^{o}F. The capital equipment cost of the ACC is comparable to that of groundlevel ACCs of similar size, although the rooflevel construction and relative lack of site accessibility resulted in significant additional construction-related costs.

The ACC has performed well during over six years of continuous operation. At no time has the plant failed to meet the 240 MW plant design output on peak hot days due to ACC cooling capacity limitations. The plant meets the noise design target of 56 dBA at 113 feet from the edge of the ACC. Periodic washdown of the tube bundles at annual or greater intervals is necessary. Principal issues are: 1) condensation of sugar compounds from the nearby sugar processing plant on the ACC tube bundles, and 2) insect buildup. Inleakage of ambient air at the north steam turbine/ACC duct interface has been an ongoing minor maintenance issue. Relatively little maintenance has been required on the ACC or ACC fans and motors since initial startup in 1996.

The transferability of the optimized height, noise, and performance characteristics of the Crockett Cogen ACC to larger combined-cycle plants is also addressed by the authors.

Evaluation of Variable Pumping Rates as a Means to Reduce Entrainment Mortalities

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Dr. John Young is a Senior Scientist with ASA Analysis & Communication, Inc. Dr. Young received his B.A. in Biology from Washington University, M.S. degrees from Pennsylvania State University and Union College, and a Ph.D. in Ecology from the City University of New York. He has studied the effects of entrainment and impingement for the last 27 years, as a consultant and while in the environmental affairs department of a major utility. His experience encompasses in-plant sampling programs to assess entrainment and impingement abundance and survival, as well as long-term source water body monitoring to determine population and community impacts

ABSTRACT

The need for water in once-through cooling systems varies seasonally with the ambient water temperature, and with the generating load. At stations whose generating load follows seasonal and/or daily demand patterns, variable-speed pumps provide a way to reduce water use and thereby the numbers of organisms entrained. When appropriate limits are placed on discharge temperatures, necessary from both plant thermodynamic efficiency and biological considerations, cooling water flow patterns may be found which can substantially reduce the number of organisms lost. The potential for reducing mortalities is enhanced for species or life stages whose pattern of abundance in the water column is counter to daily pattern of generation in peaking plants. Examples of the potential for mortality reduction are illustrated at a Hudson River generating station.

Tuesday, May 5
3:30 PM – 5:00 PM

Session C:
Costs Associated with Flow Reduction

Cooling System Retrofit Costs

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Dr. John S. Maulbetsch is currently a consultant to government and industry in the areas of energy and environment, advanced power system technologies and global sustainability. His focus in the past two years has been on water conserving alternative cooling technologies for electric power generation. From 1975 through 1998, he held a number of senior technical positions at EPRI (formerly the Electric Power Research Institute). His activities during that time included developing energy technology strategies for global sustainability, authoring "Electrification and Global Sustainability portion of EPRI's Electricity Technology Strategy Roadmap, developing and coordinating EPRI's central exploratory research effort and leading several major programs in the Environmental Control Systems area. Before joining EPRI, Dr. Maulbetsch was with Dynatech Corporation in Cambridge, Massachusetts for seven years. He was Director of the Energy Technology Center for the company. From 1965 to 1968, Dr. Maulbetsch was an Assistant Professor of Mechanical Engineering and Ford Post-Doctoral Fellow of Engineering at the Massachusetts Institute of Technology. Dr. Maulbetsch is a Fellow of the American Society of Mechanical Engineers and was a member of the Council of the American Association for the Advancement of Science representing the Engineering Section. He is the author of numerous articles on heat transfer in boiling and two-phase flow, water conservation, waste management, air quality control and global energy strategy. Dr. Maulbetsch received his S.B., S.M. and Ph.D. degrees from M.I.T. in 1960, 1962 and 1965 respectively.

ABSTRACT

This paper presents estimates and analyses of the costs and environmental trade-offs of retrofitting recirculating cooling systems using mechanical draft cooling towers onto electric power generating plants, designed for and operating on once-through cooling systems.

The scope of the project included

1. The gathering of data from utility sources of cost estimates made for retrofits at individual plants
2. An review and analysis of independent cost estimating methodologies by several different groups, and
3. A comparison of the results of the several estimates with the individual plant data.

The conclusions were:

1. Retrofit costs are highly variable from plant to plant.
2. This variability cannot be well accounted for by correlating factors such as $/kW or $/gpm of circulating water flow normally found to be satisfactory for new plant cost correlations.
3. Differences in individual plant costs cannot be accounted for by differences in plant type (fossil vs. nuclear) nor by cooling water source type (fresh, brackish, saline).
4. The variability is the result of site-specific factors associated with difficulties particularly related to the fact that retrofits present special constraint to on-site construction projects.

5. Plant retrofits can be roughly assigned a "degree of difficulty classification" as "easy', "average" or "difficult" retrofits.
   i. The costs for the easiest of the projects are roughly consistent with costs estimated for cooling system construction at new facilities and are close to $125/gpm.
   ii. The average difficulty projects costs cluster around $200/gpm +/- 20%
   iii. The more difficult projects range from $250 to $300/gpm with a few ranging as high as $700 to $900/gpm
6. Significant costs, in addition to the initial capital costs, result from cooling system retrofits including
   i. Additional power requirements for cooling system operation in the range of 1 to 1.5% of plant capacity
   ii. Additional maintenance costs in the range of 1 to 3% of system capital costs annually
   iii. Additional fuel costs resulting from efficiency reductions imposed on the plant by the inherent limitations of closed-cycle cooling systems in the range of 1% on an annual average basis.
7. Closed-cycle cooling, while reducing water withdrawals for natural waterbodies relative to once-through cooling, has environmental impacts not associated with once-through cooling, such as evaporation losses, discharge of blowdown, discharge and disposal of waste water and solid waste, drift, visible plumes, additional air emissions from increased fuel consumption and noise.

Estimating Energy Penalties for Wet and Dry Cooling Systems at New Power Plants

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BIOSKETCH

Mr. Wayne Micheletti is founder and president of Wayne C. Micheletti, Inc., an independent water and wastewater management-consulting firm. Mr. Micheletti received his B.S. and M.S. in Chemical Engineering from the University of Texas at Austin. He worked as a Senior Engineer and Group Leader of the Water Processes Group at Radian Corporation for 6½ years, directing field and laboratory studies, software development and technology assessments. He then became a Senior Project Manager for the Electric Power Research Institute where he guided EPRI research for 8 years in the areas of cooling water systems, ash handling systems, wastewater treatment, and low volume waste management. Since 1991, he has been an independent consultant. He specializes in all aspects of water and wastewater management, from intake to discharge, and has worked with a wide variety of industrial, commercial, institutional and governmental clients.

ABSTRACT

One means for reducing the impingement and entrainment of aquatic organisms at new power plant cooling water intakes is to reduce the total volume of water withdrawn from the surface water source. A wet recirculated cooling system (cooling tower) withdraws about 10% as much water as a wet once-through cooling system. A dry cooling system (air-cooled condenser or ACC) has a still lower withdrawal rate. While the choice between a wet cooling tower and an ACC for a new power plant will depend upon a number of site-specific factors, economics is always an important consideration. And the total life-cycle cost for a new cooling system can be significantly influenced by the system's ability to continuously operate at design efficiency during widely varying climatic conditions throughout the year. A decline in cooling system efficiency can result in a decline in power generating efficiency due to insufficient cooling of the turbine exhaust steam and an increase in turbine backpressure. The associated loss of generating capacity is frequently referred to as an "energy penalty". Although this "penalty" is normally associated with steam turbine-generator operation, in some circumstances the combustion turbines in a combined-cycle power plant also can be affected. Therefore, anyone involved in the specification, evaluation, selection or approval of new power plant cooling systems should understand the subtle, but critical economic consequences of estimating energy penalties. This paper will explain the energy

penalty concept in detail by describing the data that are needed, explaining the implications of key assumptions and showing how these data and assumptions can influence subsequent estimates.

A Tool for Budgetary Estimation of Cooling Towers Unit Costs Based on Flow

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BIOSKETCH
Dr. Faysal Bekdash is a section manager and senior engineer at Science Applications International Corporation (SAIC). Dr. Bekdash has a Ph.D. from University of Maryland, College Park, Diplôme de Spécialisation Post-Universitaire, from IAM, Italy, Diploma of Ingénieur Agricole, AUB, and B.Sc. from AUB. Dr. Bekdash has 22 years of extensive experience in development projects. He served as a juror on the Army Corps of Engineers Chief of Engineers Design and Environmental Award Program for the year 2002. He served on DOE and NOAA research proposals review panels (2002) (Bioremediation and Biotechnology). Co-author of a white paper submitted to DOE (2002) on research needs in the area of water use by power plants. The U.S. Environmental Protection Agency (EPA) Office of Water presented him with the Tribute of Appreciation award in 1991. Dr. Bekdash is a lead technical-person in charge of evaluating and costing standard and emerging technologies in areas related to power plants and water/wastewater treatment plants. He is the work assignment manager (WAM) for SPARRC (Software to Ascertain Radionuclides Residuals Concentrations). He served as an expert witness, for the State of California, on wastewater treatment compliance costs and technologies= efficacy and feasibility. He served as an instructor, for a course on hazardous waste and hazardous material management (in Italian) to local personnel at Camp Darby base (US army, Italy). Dr. Bekdash has national and international experiences in development projects. As a consultant to SAIC, he provided technical support for two forecast energy-related economic studies (the Middle East and beyond and the ex-Soviet central Asian States plus Iran). The studies looked into the feasibility of various regional development scenarios, available and needed resources, political systems, points of conflict and resolution mechanisms.

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Mr. Michael Moe is a senior engineer and project manager with the Environmental and Health Sciences Group of Science Applications International Corporation (SAIC). Mr. Moe received his B.S. in Chemical Engineering from Rice University and his M.S. in Chemical Engineering from the University of Texas at Austin. He set up and ran an analytical laboratory for four years at Wilson Oxygen & Supply Co. in Austin, Texas. He then joined the Oklahoma Department of Environmental Quality, where he worked in the Industrial NPDES Permit Unit for six-and-a-half years, the last two of which he served as Permit Unit Supervisor. His responsibilities included overseeing the drafting and issuance of industrial discharge permits, as well as maintaining and updating the State's Continuing Planning Process document, which addressed the State's procedures for watershed management. For the last four years at SAIC, Mr. Moe has led SAIC's support to EPA for development of NPDES permits and NPDES regulations for cooling water intake structures and for concentrated animal feeding operations (CAFOs).

ABSTRACT
A parametric model for estimating cooling towers cost was developed based on re-circulating cooling water flow unit ($/gpm or $/L/min). Given the complexity and diversity of cooling towers, a parametric model based on flow appears to be the most cost-effective way for preliminary unit cost estimate. The new cost model is

applicable for regulatory and compliance purposes at national level. Estimating costs of various environmental regulations at the unit technology level can be very challenging for engineers. Cooling towers costs are so site-specific, an individual or a few site-specific cost estimates would not be appropriate on a national basis. Therefore, the cost estimator has to develop a unit cost that is representative of cost incurred by regulated communities across the different regions of the United States. This paper present the method used in the development and the validation of the parametric model. It also presents ideas for research in areas of reducing dependency on water as a medium for cooling in power plants and other industries.

Power Plant Repowering as a Strategy for Reducing Water Consumption at Existing Electric Generating Facilities

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Mr. David Schlissel is a Senior Consultant at Synapse Energy Economics. Mr. Schlissel received a B.S. from M.I.T. and an M.S. from Stanford. Both degrees were in Aeronautical and Astronautical Engineering. He also received a Juris Doctor Degree from Stanford Law School. In addition, he has studied Nuclear Engineering and Project Management at M.I.T. Prior to joining Synapse in November 2000, Mr. Schlissel was the president of Schlissel Technical Consulting, Inc. and its predecessor, Schlissel Engineering Associates. He has over 29 years of experience in energy and environmental work. Mr. Schlissel's recent projects have included analyses related to power plant cooling system design issues, the repowering of older electric generating facilities, electric transmission and distribution system reliability, and the environmental benefits that would be provided by proposed electric generating and transmission facilities.

ABSTRACT

The "repowering" of a power plant involves replacing the older, inefficient equipment in the plant with new equipment, usually combined-cycle technology. Repowering also can result in the creation of additional generating capacity as part of the "repowered" facility. This study examines the environmental and economic impacts of using repowering as a strategy to reduce adverse water impacts at electric generating facilities.

First, the study examines the experience to date with repowering, reviewing the publicly available information concerning the cost of repowerings and the reductions in water consumption that have been achieved at repowered facilities. Second, we examine as case studies several recent repowerings. Cases are explored in terms of expected changes in plant performance, forecast reductions in water and air impacts, and projected costs. Finally, we compare the costs and benefits of repowering to other possible options for reducing water usage at existing power plants.

Key findings will include the following:

- A repowered electric generating facility can produce additional revenues through increased sales because (1) it can generate electricity at lower cost than older, less efficient units and (2) it can add new generating capacity as part of the repowering process. These additional revenues will offset the costs of transitioning to a closed-cycle cooling system.
- Repowering can make retrofitting an existing power plant to a closed-cycle cooling system a more attractive option.
- Repowering also can achieve secondary effect reductions in water usage at other power plants in the region, where generation decreases as a result of the operation of the new, more efficient repowered plant.

Wednesday, May 7
8:20 AM – 9:30 AM

Session D-1:
Screening and Other Fish Diversion/Deterrent Technologies

Fish Return System Efficacy and Monitoring Studies for JEA's Northside Generating Station

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Ms. Isabel Johnson is the Environmental Toxicology Practice Leader for Golder Associates, Inc. Ms. Johnson also serves on the Board of Directors for Golder Associates Inc. and has a Courtesy Scientist appointment at the University of Florida's College of veterinary medicine, Center for Environmental and Human Toxicology. Ms. Johnson holds a Bachelor of Science degree in Zoology from the University of Florida and a Master of Science degree specializing in Marine Biology from the University of West Florida. Ms. Johnson is responsible for management of multidisciplinary projects for the power and manufacturing industry, marine and freshwater aquatic studies, and ecological risk assessments. Her efforts in these studies include thermal assessments, development and implementation of aquatic biological programs, evaluations of industrial effluent impacts, and NPDES compliance.

ABSTRACT
The Jacksonville Electric Authority (JEA) Northside Generating Station is located in a tidal estuarine area adjacent to San Carlos Creek, a tributary to the St. Johns River, Florida. The plant is approximately 10 river miles from the Atlantic Ocean, and the plant's cooling water intake flume draws water from the St. Johns River. The Station discharges cooling water to the San Carlos Creek. The intake structures at the plant consist of concrete-lined bays approximately 30 feet deep, a set of continuous-belt traveling screens, and electrically driven impeller pumps for circulating the cooling water.

The North Generating Station's fish return system (FRS) is an array of trays, wash sprays, and sluice channels designed to remove impinged organisms from the traveling screens and deposit them into San Carlos Creek. Each FRS has a rotating traveling screen (0.5-inch mesh) with collection pans attached approximately every four feet. As the traveling screens rotate, low pressure sprays rinse the biota from the screens into the fish pans; the biota are then flushed with the water over a rubber lip into the fish return troughs. All troughs join a main trough that returns impinged biota to the San Carlos Creek. The traveling screens are then back-flushed with a high pressure spray wash to remove debris.

Numerous monitoring studies have been conducted by JEA to evaluate the efficacy of this FRS since the late 70s, including monitoring studies for routine operation as well as evaluations of alternative schedules for operation in order to optimize the operation and maintenance of the FRS, while maintaining the efficiency of return and survival of aquatic organisms impinged upon the screens of the FRS.

This paper will present the outcome of these numerous studies, including a brief review of monitoring data available for the past 20 years, as well as the outcomes of the optimization assessments for the FRS.

Effectiveness, Operation and Maintenance, and Costs of a Barrier Net System for Impingement Reduction at the Chalk Point Generating Station

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Mr. Bailey is currently Group Leader, Water and Land Management Services for Mirant Mid-Atlantic. His responsibilities include tracking new environmental regulatory developments, providing environmental permitting and compliance support services and management of Mirant Mid-Atlantic's environmental stewardship programs. Mr. Bailey has over 30 yrs. experience working on environmental issues in the electric power generation industry. This includes 25 yrs. of experience working on 316(a) and (b) issues. Mr. Bailey currently serves as Chair of the Utility Water Act Group's Cooling Systems Committee, which has played a lead role in representing the Industry during the 316(b) rulemaking. Mr. Bailey also serves as Co-Chair of the Electric Power Supply Association 316(b) workgroup and serves as an advisory to EPRI on 316(b). Mr. Bailey has also served as Chair of the Environment Section for Southeastern Electric Exchange and has served as President of the Alliance for the Chesapeake Bay.

ABSTRACT

A barrier net was first deployed at the Chalk Point Generating Station on the Patuxent River Estuary in 1981 to prevent Unit outages caused by juvenile blue crabs circumventing the traveling screens and blocking cooling water condenser tubes. As a result of successful deployment, effectiveness of the net was evaluated for use as Best Technology Available for reducing impingement under Maryland's Cooling Water Intake Structure Regulations. The technology was determined to meet the standard of BTA under Maryland's regulations and was viewed as a very cost effective compliance mechanism by the Company. The paper will evaluate effectiveness of the Chalk Point barrier net in reducing impingement of the most commonly impinged species. Baseline impingement data collected prior to net deployment will be compared to post deployment impingement data. The effectiveness evaluation includes consideration of population fluctuations in the source water through use of state and locally collected indices and impingement monitoring data collected over a period of more than two decades. The paper will discuss annual operation and maintenance measures needed to maintain net effectiveness in a relatively high fouling estuarine environment. The paper also includes a discussion of changes made in operation and design of the system to improve fish protection performance. Finally the paper will provide information on the capital, and O&M costs of the technology.

Reductions in Impingement Mortality Resulting from Enhancements to Ristroph Traveling Screens at an Estuarine Cooling Water Intake Structure

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Mr. Kenneth Strait is the Project Manager for the Public Service Enterprise Group Estuary Enhancement Program and is responsible for the ongoing cooling water intake studies, wetland restoration efforts, fish ladder installations, and biological monitoring programs associated with PSEG's Salem Generating Station. Ken received his B.S. and M.S. in Wildlife Resources from West Virginia University and is pursuing his Ph.D. in Ecology at Rutgers University. He has been involved in cooling water intake, Section 316(b), and related fisheries research for 20 years. The Estuary Enhancement Program (EEP) is the largest privately funded wetland restoration program in the country. It includes a combination of environmental and technological enhancements designed to reduce and offset potential adverse environmental impacts of the Salem Generating Station cooling water intake.

ABSTRACT
Concern exists regarding losses of fish and other aquatic organisms due to the operation of steam electric plant cooling water intake structures (CWIS). Generally, solutions to address this issue have focused on improvements to the technologies employed at the CWIS to protect fish. At some plants, integrated solutions that include ecologically beneficial measures have been implemented and the ecosystem benefits can exceed those obtainable through solely technology-driven solutions. An integrated approach that includes intake modifications to reduce losses; the restoration, enhancement and preservation of tidal marsh; the installation of fish ladders; and extensive biological monitoring was required for the Salem Generating Station (SGS) in the Delaware Estuary.

In 1995, the PSEG Nuclear LLC, installed improved Ristroph traveling screens at the SGS. The modified screens are effective at improving fish survivability, with the average effectiveness, over all species studied, exceeding 50 percent. Impingement mortality rates at Salem are now less than half of what they were with the original screens.

The effectiveness of the screens for reducing mortality is dependent on species and months involved. For striped bass, white perch and spot, abundance weighted impingement mortality was low. Average total mortality for this group is less than 10% (4.7%, 6.3%, and 6.7%, respectively). For Atlantic croaker, American shad, and blueback herring, mortality estimates were higher at 22.6 %, 23.9 %, and 27.3%, respectively. Weakfish and bay anchovy estimates (47.8% and 58.0%, respectively) have also improved from historical values.

Additional studies to identify other components of the CWIS that might be improved to further reduce impingement mortality indicated that changes to the design or operation of the fish return system would not improve overall fish survival. Two potential stressors, the fish collection pool and the terminus of the fish return pipe, were evaluated using computational flow dynamics modeling and live fish testing. Results indicate that these components are not significant contributors to mortality.

Biological monitoring of the benefits resulting from the restoration of over 10,000 acres of tidal marsh and the installation of eight fish ladders on tributaries to the Delaware Estuary indicate that these enhancements are providing substantial aquatic production to the ecosystem. The monitoring programs are providing valuable scientific information for managing natural resources in the Delaware Estuary and have demonstrated the long-term ecological benefits of an integrated approach for addressing the complex environmental concerns relating to cooling water system impacts.

Wednesday, May 7
10:00 AM – 11:30 AM

Session D-2:
Screening and Other Fish Diversion/Deterrent Technologies, cont'd

Development and Operation of Acoustic Fish Deterrent Systems at Estuarine Power Stations

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Dr. Andy Turnpenny is a fish biologist and is currently Managing Director of Fawley Aquatic Research Laboratories and Fisheries Director of Fish Guidance Systems Ltd, both located in Southampton England. Andy spent 15 years as an environmental research scientist with the UK power industry and was formerly head of aquatic research for National Power PLC. He has specialized in fish entrainment and fish screening and passage issues.

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Dr Jeremy Nedwell is an engineer in underwater acoustics and previously headed the underwater acoustics laboratory at Southampton University, England. He is Managing Director of the UK underwater acoustics consultancy Subacoustech Ltd and Engineering Director of Fish Guidance Systems Ltd. Jeremy has specialized in environmental acoustics.

ABSTRACT
Sound-projector-array- (SPA-) based acoustic fish deterrent (AFD) systems were developed initially in the early 1990's in response to fish mortality issues at UK estuarine and coastal generation stations. Early systems suffered technical problems but were sufficiently successful to encourage further development, allowing the key problems to be overcome. SPA AFD systems have been trialled or permanently installed at five UK estuarine power stations and one Belgian plant approvals have been obtained to install others.

The paper will outline the operating principles of SPA AFD systems, review operating experience over ten years of use at estuarine sites and present results of scientific trials.

Induced Sweeping Flows at CWIS for Reducing Fish Impingement

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Dr. Charles Coutant is Distinguished Research Ecologist in the Environmental Sciences Division of Oak Ridge National Laboratory. Dr. Coutant received his B.A., M.S., and Ph.D. in biology (ecology) from Lehigh University. He conducted field and laboratory studies on Pacific salmon in relation to nuclear power stations on the Columbia River for 5 years at the Atomic Energy Commission's Pacific Northwest Laboratory. He led a program on power station effects on aquatic systems at Oak Ridge National Laboratory (Tennessee) in the 1970s and early 1980s, and has held various research and administrative positions there for 33 years. He was active in developing guidelines for, and implementing, 316(a) and 316(b) demonstrations. Since 1989 he has served as an independent advisor for the salmon restoration programs in the Columbia River basin. His main interests are temperature effects, fish behavior and habitat selection, and research and analysis for minimizing the impacts of thermal-electric and hydropower generation on aquatic systems.

ABSTRACT

We propose induction of an angled sweeping flow at cooling-water intakes (CWIS) as an innovative technology to reduce impingement by guiding fish to a screen bypass that returns fish to the waterbody. The concept arises from specification of a "sweeping velocity" by several state and federal agencies to protect fish from being impinged at water intake screens, primarily angled fish screens at irrigation water diversions in the Pacific Northwest. A sweeping velocity is the velocity component parallel to the angled screen face in contrast to the velocity perpendicular to the screen face. Although there is disagreement over whether the sweeping velocity is anything other than a theoretical vector, screens that are angled according to the calculations for meeting the sweeping velocity criteria are generally effective in diverting fish to bypasses. Most existing CWIS intake screens are not angled and were not constructed to provide a sweeping velocity to a bypass. The typical CWIS has vertical traveling screens mounted perpendicular to the overall intake flow, often in an intake canal. Some perpendicular intake screens are mounted very close to the flow of a river, nearly flush with the riverbank, with a design (containing a sweeping flow in the direction of river flow) that is recognized as having generally low rates of impingement. Replacing existing screens with angled screens designed to steer fish toward a bypass may be cost prohibitive for existing facilities. Alternately, we propose that an angled sweeping flow induced (by pumps or baffles) upstream of existing screens could effectively guide fish away from impingement on the screens and into a bypass. If proven effective, such a hydraulic barrier would not require extensive structural modifications of existing screens other than provision of a bypass to the source water body. This paper reviews the existing regulatory criteria for sweeping flows, presents a possible layout for inducing sweeping flows at a CWIS, predicts fish behavior based on previous studies, and outlines proposed studies to test the hypothesis in laboratory flumes and at an existing CWIS.

The Use of Angled Bar Racks and Louvers for Protecting Fish at Water Intakes

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Dr. Steve Amaral is a Senior Fisheries Biologist with Alden Research Laboratory, Inc. Steve received his B.S. and M.S. degrees in Fisheries Biology from the University of Massachusetts. During the past 12 years, he has been heavily involved in the development and evaluation of fish passage and protection technologies for use at water intakes. Prior to joining Alden nine years ago, Steve worked on fish passage projects for the Massachusetts Cooperative Fish and Wildlife Research Unit and Stone and Webster Engineering. Working with his colleagues at Alden, he has conducted numerous laboratory and field studies with many different technologies and fish species. Recent studies have included biological evaluations of a fish-friendly hydro turbine, wedgewire screens, angled bar racks and louvers, and behavioral deterrents.

ABSTRACT
Angled bar racks and louvers have been used to effectively guide fish away from water intakes. These technologies have been applied mainly at hydroelectric projects, with some installations occurring at irrigation diversions and one at a cooling water intake structure. Although guidance efficiency rates have varied among sites, available data suggest that angled bar rack and louver arrays can effectively guide a wide range of species and size classes. Successful application appears to be dependent on producing hydraulic conditions that have been shown to elicit avoidance responses from particular species and sizes classes. The performance of existing installations and results form recent studies indicate that angled bar rack and louver arrays have potential for effective application at cooling water intakes. Fish that are potentially vulnerable to impingement could be guided downstream past an intake or to a fish return sluice. Effective guidance will depend primarily on the behavior and swimming abilities of target species, physical design of a guidance system (e.g., angle of array to approaching flow, slat spacing), and the presence of hydraulic conditions (e.g., turbulence near bar and louvers slats, approach velocity, bypass velocity) that elicit strong avoidance responses. Field and laboratory studies have demonstrated that guidance rates as high as 90 to 100% can be achieved depending on species, fish size, and guidance array design. The presentation will review the recent results of EPRI sponsored laboratory evaluations of bar racks/louvers and discuss potential application of bar racks and louvers for fish protection at CWIS.

A Review of Impingement Survival Studies at Steam Electric Power Stations

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Dr. Steven Jinks is a senior scientist and president of ASA Analysis & Communication, Inc. Dr. Jinks received his B.S. in biology from Rutgers University in New Jersey, his M.S. in radiological health, and his Ph.D. in environmental science from New York University. He researched the environmental fate and human health effects of radionuclides for 4 years as an associate research scientist at New York University. He then conducted ecological risk, impact assessment, and water quality studies as a consulting scientist, most recently at ASA Analysis & Communication, the firm he founded in 1997. His work on aquatic impacts from power plant operation extends over the past 27 years.

ABSTRACT
EPA has recently proposed draft §316(b) regulations for existing power producing facilities that contain performance requirements based, in part, on reducing fish and shellfish impingement mortality at the cooling water intake structure by 80% to 95% relative to a baseline consisting of a shoreline intake with no impingement controls. Analyses of the potential for focal species to survive impingement for both existing and alternative intake design and operation will be important for demonstrating compliance with this requirement. Recognizing this fact, EPRI has recently sponsored a review of the historical studies on impingement survival. The majority of impingement survival studies were conducted between the mid-1970s and mid-1980s, as part of the initial surge of activity in response to the requirements of §316(b) of the Federal Water Pollution Control Act Amendments of 1972. The review included studies at 31 steam-electric plants located in 15 states and the province of Ontario, covering all four of the major waterbody types for which USEPA has proposed §316(b) performance requirements. Various biological, CWIS, and water body factors have been shown to influence

impingement survival rates, but no generally applicable mechanistic models for predicting impingement survival have been developed. Results of the review indicate that over half of the taxonomic families of fish and shellfish studied to date have the potential for impingement survival rates of 70% or higher with adequate screen design and operation. Reported data also indicate that modifying screenwash operation to a continuous mode is one of the most effective means for enhancing impingement survival. Uses and limitations of the historical studies and available summaries and a database of key information from the historical studies are discussed.

Wednesday, May 7
1:00 PM – 2:50 PM

Session D-3:
Screening and Other Fish Diversion/Deterrent Technologies, cont'd

Optimal Slot-Width Selection for Wedgewire Screens

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Mr. William Dey is a Senior Scientist and Vice President of ASA Analysis & Communication, Inc. He has 28 years of experience conducting ecological risk assessments of man's activities on the aquatic environment. He has conducted ecological risk assessments of power plant cooling water intake systems to freshwater, marine, and estuarine habitats throughout much of the United States. Mr. Dey currently directs the development and implementations of mathematical models to assess the population-level consequences of large scale cooling water withdrawals and to evaluate the potential benefits of intake alternatives.

ABSTRACT

Cylindrical wedge-wire screens have the potential to substantially reduce the loss of aquatic organisms resulting from cooling water withdrawals. This is especially true in riverine and estuarine locations where ambient velocities far exceed velocities induced by the water withdrawal. However, the surface area and hence, size and cost, of a wedgewire intake system increases as the slot width gets smaller. Therefore data on the relative abundance of each length category of focal species in the vicinity of the intake is critically needed for optimally selecting the slot width of the wedge-wire screens. This fact is illustrated using actual ichthyoplankton data from the Hudson River estuary and assuming a new 500 MGD cooling water withdrawal at three locations. The focus of this assessment is on the marine species, bay anchovy, and anadromous species, striped bass and American shad. This analysis estimates the reduction in equivalent loss (i.e., biological benefit) that would occur at each location with a variety of wedgewire slot widths. The results demonstrate that the shape of the cost-benefit curve across slot widths varies depending on species and location. Consequently, it is imperative that site-specific biological data be considered when designing a wedge–wire intake system that meets regulatory requirements at the lowest cost possible.

Development of Filter Fabric Technology to Reduce Aquatic Impacts at Water Intake Structures

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Harbor. He also works with several power generating facilities to assess the feasibility of new technologies to reduce entrainment of fish.

ABSTRACT

The determination of best technology available (BTA) to mitigate environmental impacts is influenced by several site-specific variables that work alone or in concert including water withdrawal volume, intake type and configuration, facility operation, source water characteristics, and economic considerations. One innovative technology that is a BTA candidate at a once-through cooling system on the Hudson River Estuary is the Gunderboom Marine Life Exclusion System™ (MLES™), a full-water-depth fabric filter barrier that has been shown to effectively limit aquatic biota entrainment at water withdrawal intake structures.

A fabric filter barrier system, originally designed by Gunderboom, Incorporated as a sediment barrier and oil boom, was modified and developed for use at water intake structures. The fabric filter barrier technology was developed over a six-year (1995-2000) period as part of a research and development program sponsored by Mirant New York LLC. The MLES™ development program was conducted at the Lovett Generating Station, which has a once-through condenser cooling water system with a capacity of 491 MGD. To support the MLES™ development, numerous bench scale and *in situ* large-scale support studies were conducted to evaluate entrainment, impingement and the influence of biological growth on the fabric.

Full-scale deployments, scheduled to coincide with the seasonal presence of fish eggs and larvae, were used to develop and improve the technology and assess its effectiveness. The MLES™ is designed to exclude entrainable fish eggs and larvae withdrawn at the water intake structure by filtering the total water volume required by the facility, while taking into consideration site water quality (sediment loading) and hydraulic conditions (tides, current velocities).

Ichthyoplankton monitoring was conducted during the development program to measure the systems effectiveness at reducing organism passage. Paired samples were collected at protected (i.e. within the MLES™) and unprotected intakes during the 1995, 1998 and 2000 deployments. Results from the ichthyoplankton-monitoring programs indicate that the Gunderboom MLES™ was approximately 80% effective at reducing entrainment. Laboratory studies established the robustness of the eggs and larvae of several fish species to impingement on the fabric. Other studies and literature confirm similar results for early life stages of other Hudson River species. As a result of this development program, the Gunderboom MLES™ is proposed to be BTA for mitigating environmental impacts associated with the use of surface waters at several Hudson River intake structures.

Vulnerability of Biofouling of Filter Curtain Materials Used for Entrainment Reduction

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Dr. Peter Henderson is a director of Pisces Conservation Ltd and a Senior Research Associate of the Department of Zoology University of Oxford, England. Dr Henderson obtained both bachelors and doctoral degrees from Imperial College, London. He has worked for more than 25 years in ecological research, and lectures on population ecology and ecological methods at Oxford. He co-authored with Sir Richard Southwood the third edition of the textbook 'Ecological Methods', and subsequently recently wrote "Practical Methods in Ecology". His taxonomic specialty is freshwater ostracoda and he wrote the Linnean Society Synopsis of British species. He is a specialist in population dynamics and tropical and temperate crustacean and fish ecology and has worked extensively on the conservation of wetlands in Amazonia. He worked for many years with late Prof. W. D. Hamilton on the theory of evolution. Since first starting post-doctoral studies he has worked on the ecological effects of power stations and has been studying the fish and crustacean population dynamics in the Bristol Channel since 1980 using samples of animals impinged on cooling water intake screens.

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UK

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Dr Richard Seaby is a director of Pisces Conservation Ltd. Dr Seaby obtained his bachelors degree from the University of London. His doctoral degree was from Liverpool University. He has worked for 10 years as an ecological consultant specializing in the aquatic environment. He has worked on impingement and entrainment issues in many different situations and has been involved in a long-term study into the population of fish and invertebrates in the Bristol Channel since graduation. He specializes the aquatic environmental impact of industrial and construction projects.

ABSTRACT
The need to reduce the passage of planktonic aquatic life, particularly fish eggs and larvae, through the condenser cooling water circuits of direct-cooled power plants is widely acknowledged. While this could be achieved by the conversion to closed-cycle cooling it has been suggested that a more cost-effective approach would be to protect the intakes with fine-mesh filter curtains that would stop the entry of plankton. For a number of years a filter system designed by Gunderboom Inc. has been has been experimentally deployed at the Lovett Generating Station in the Hudson Estuary. It was suspected that a potential weakness with such filters was their vulnerability to biofouling, which would reduce permeability and damage the fabric. Tests for biofouling of the Gunderboom filter material were undertaken in the Hudson Estuary in summer 2001. These tests showed that the Gunderboom material was capable of becoming rapidly colonized by a community of bacteria, plants and animals. This fouling community developed steadily over a 30-day study period and would almost certainly have continued to develop further if the observations had been continued. Of particular significance was the colonization and blockage of the 1 mm pores in the material by tube building crustaceans. A panel through which water was pumped and which was cleared of silt by airburst cleaning fouled more quickly than panels in static water without airburst cleaning. There was a highly significant reduction in permeability linked to biofouling and a reduction of almost 97% was observed in the panel exposed to flowing water with air-burst cleaning. These simple observations show the vulnerability of filter systems to fouling and indicate the need for further long-term testing before they can be considered as a viable technology for the reduction of entrainment at estuarine and marine cooling water intakes.

Laboratory Evaluation of Wedgewire Screens for Protecting Fish at Cooling Water Intakes

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Dr. Steve Amaral is a Senior Fisheries Biologist with Alden Research Laboratory, Inc. Steve received his B.S. and M.S. degrees in Fisheries Biology from the University of Massachusetts. During the past 12 years, he has been heavily involved in the development and evaluation of fish passage and protection technologies for use at water intakes. Prior to joining Alden nine years ago, Dr. Amaral worked on fish passage projects for the Massachusetts Cooperative Fish and Wildlife Research Unit and Stone and Webster Engineering. Working with his colleagues at Alden, he has conducted numerous laboratory and field studies with many different

technologies and fish species. Recent studies have included biological evaluations of a fish-friendly hydro turbine, wedgewire screens, angled bar racks and louvers, and behavioral deterrents.

ABSTRACT

Cylindrical wedgewire screens are considered a technology that has potential for minimizing entrainment and impingement of aquatic organisms at cooling water intakes. An EPRI-EPA sponsored (under the U.S. EPA Water Quality Cooperative Grant Program) laboratory evaluation of cylindrical screens was conducted to determine hydraulic and design criteria that contribute to greater protection of fish larvae and eggs. Entrainment and impingement rates associated with various slot sizes, slot velocities, and channel velocities were estimated for early life stages of eight species of fish. In general, entrainment increased with slot size and slot velocity and decreased with channel velocity and larval length. Impingement also increased with slot velocity and decreased with channel velocity, but, unlike entrainment, decreased with slot size. Interrelationships existed among the various test parameters (e.g., the effects of slot velocity were not uniform for all slot sizes evaluated and response of larvae to varying hydraulic conditions was related to fish size and swimming ability). The results of this study demonstrate that cylindrical wedgewire screens are capable of reducing entrainment and impingement rates to low levels for most species and life stages of fish. However, optimum design criteria will differ depending on biological factors and hydraulic conditions. Future studies, whether conducted in the laboratory or field, should focus on a narrower range of screen design and hydraulic parameters in order to better define the relationships between the various parameters and effective protection of fish larvae and eggs.

Selection and Design of Wedgewire Screens and a Fixed-Panel Aquatic Filter Barrier System to Reduce Impingement and Entrainment at a Cooling Water Intake Structure on the Hudson River

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Mr. Mark Strickland is the Corporate Environmental Issues Manager at PSEG Services Corporation serving the Public Service Enterprise Group family of companies. Mr. Strickland received his B.S. in Mechanical Engineering from Virginia Polytechnic Institute and State University and his M.B.A. in Industrial Management from Fairleigh Dickinson University in New Jersey. After starting his career in power plant engineering (nuclear and fossil steam supply systems, and air pollution control equipment), he moved into the environmental area 17 years ago where he has managed a variety of environmental programs and issues at a corporate level. His work has focused mainly on water issues and has included permitting, environmental studies and investigations, 316(a) and (b) demonstrations, regulatory affairs and issues management.

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Dr. James Mudge is a Principal Environmental Scientist at Civil & Environmental Consultants, Inc. located in Pittsburgh, Pennsylvania. Dr Mudge received his B.S. in Biology from Mansfield University in Pennsylvania and his M.S. and Ph.D. in physiology from the Pennsylvania State University. He has thirty years of environmental monitoring, impact assessment, and permitting experience working both for electric utility and environmental consulting firms. He has designed and implemented 316b studies in Pennsylvania, New York, New Jersey, and Washington. His main interests are in assessing the effects of electric generating facilities on aquatic ecosystems and ecological risk assessment.

ABSTRACT

In 2001 the New York Department of Environmental Conservation (DEC) approved the retirement of the existing once-through cooling water system at the Albany Steam Generating Station (ASGS) site and replacement with the Bethlehem Energy Center (BEC) which includes a new cooling water intake structure (CWIS). The BEC is a 750-megawatt combined cycle power plant that is being built on the western shore of the Hudson River in Bethlehem, New York. PSEG Power New York, Inc (PSEGNY) evaluated various cooling system alternatives (i.e., once-through, wet towers, hybrid towers, and dry towers) and optional measures (floating and fixed-panel aquatic filter barrier systems, and cooling water holding tank). The alternative cooling systems study prepared by PSEGNY considered many factors such as the effects on aquatic organisms, system performance, noise, aesthetics, air emissions, and costs.

Based on the results of past impingement and entrainment studies at ASGS and other Hudson river power plants, the effect of the various alternatives on four selected target species: river herring (alewife and blueback herring), American shad, white perch, and striped bass, were evaluated by various impact indicators (e.g., organism losses, equivalent adult numbers and biomass, conditional mortality rates).

The alternative selected as the best technology available (BTA) for BEC consists of 2-mm wedgewire screens and a seasonally-deployed fixed-panel aquatic filter barrier system coupled with a hybrid cooling tower. This alternative is projected to virtually eliminate impingement and reduce entrainment by about 98 to 99% as compared to ASGS and as evaluated by the aforementioned aquatic impact indicators.

This paper will overview the alternatives study process and results, describe the design of the fixed- panel aquatic filter intake barrier and why it was selected over the floating panel design for BEC, and present the operational monitoring program that will be used to determine the effectiveness of the system.

Wednesday, May 7
3:15 PM – 4:15 PM

Open Discussion
Identify Research Needs

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James Elder is an experienced facilitator having served in that capacity at two previous meetings on cooling water. Prior to his retirement from the U.S. Environmental Protection Agency in 1996, he served as Director of the Office of Ground Water and Drinking Water and before that as Director of the Office of Water Enforcement and Permits. Earlier in his career he spent a year at the Potomac Electric Power Company as part of the President's Executive Exchange Program. More recently, Elder has been a consultant to Procter & Gamble's PUR Water Filtration Products. In addition, he is the President of the Reston Youth Basketball League and is a certified part-time tennis instructor for the community of Reston, Virginia. Mr. Elder received his B.A. from Johns Hopkins University and did graduate work in international relations at George Washington University.

Poster Presenters

Improved Marine Life Recovery Technology for Circulating Water Traveling Band Screen Application

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Mr. Mark Bell is the Sales Manager – Industrial Products for Brackett Green USA, a manufacturer of Intake Traveling Band Screens, Bosker Trash Rakes and other raw water intake system products for the Electric Power, Industrial and Municipal markets. Mr. Bell received his B.S. in Business Administration from Cardinal Stritch University in Milwaukee, Wisconsin. With over 25 years of experience in the water and wastewater industry, he has been involved in all facets of the design, application and operation of traveling band screens throughout North America. As a past participant in the Fall River Renaissance in the Commonwealth of Virginia, Mr. Bell has been involved in numerous fish protection applications. Currently manages Brackett Green USA's sales efforts in the Industrial/Power markets as they relate to the new 316b regulations.

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Mr. Trent Gathright is the Marketing Manager for Brackett Green USA, a manufacturer of Intake Traveling Band Screens, Bosker Trash Rakes and other raw water intake system products for the Electric Power, Industrial and Municipal markets. Mr. Gathright is perhaps the most technically experienced individual currently active in the raw water intake market. With over 25 years of experience in the water and wastewater industry, his accomplishments in the concept design, application and operation of fish protection Brackett Green USA Traveling Band Screens and Bosker Trash Rakes are well documented. Currently manages Brackett Green USA's sales/marketing efforts in both the Industrial/Power and Municipal markets, where he is integral in the adaptation of the Brackett Green Fish Protection System into the new 316b regulations.

ABSTRACT

Introduction of EPA regulation 316b of the Clean Water Act is the latest effort by the Federal Government to minimize the impact of high mortality rates in aquatic life. The utilization of cooling water intake structures as the accepted practice of drawing water from lakes, rivers and oceans for both industrial and municipal applications has necessitated the creation of new, more efficient designs of fish handling and return systems for traveling band screens. This paper summarizes the various forms of fish protection systems as applied to Intake Traveling Band Screens at new and existing circulating water cooling intake structures. These proven technologies can be, and have been, applied at a vast cross section of electric utilities, industries and municipalities throughout North America. Areas of discussion will include: Entrance and exit velocity issues; marine life capture and return theory; separation of marine life from debris; hydraulic stabilization concerns; mesh opening size and configuration. Improvements in impingement survival rates as summarized in case studies from a power plant with fish protection traveling screens will be presented. Also included will be cost impact issues as they relate to the retrofitting of fish protection systems at new and existing intake structures.

Biological Evaluation of Aquatic Filter Barrier Material in the Laboratory

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Mr. Jonathan Black is involved with various aspects of biological issues related to fish protection at cooling water intake structures (CWIS) and downstream and upstream fish passage at hydroelectric projects. He conducts biological evaluations of fish protection technologies in both laboratory and field settings. Current responsibilities include conducting laboratory tests of aquatic filter barriers with several larval fish species, assisting in laboratory evaluations of a fish return system, and developing comprehensive reports on the status of fish protection technologies at both CWIS and hydroelectric projects.

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Mr. Timothy Hogan is a senior environmental associate at Alden Research Laboratory. He is involved with various aspects of biological issues related to fish protection at cooling water intake structures (CWIS) and downstream and upstream fish passage at hydroelectric projects. He conducts biological evaluations of fish protection technologies in both laboratory and field settings. Current responsibilities include conducting laboratory evaluations of aquatic filter barriers with several larval fish species, conducting laboratory evaluations of fish response to behavioral barriers, developing comprehensive reports on the status of fish protection technologies at both CWIS and hydroelectric projects, larval rearing of test species, and quality assurance and quality control of daily testing protocols

ABSTRACT

Aquatic Filter Barrier (AFB) is a permeable fabric material that can be considered for use as a method for reducing the entrainment of ichthyoplankton into cooling water intake structures (CWIS). We evaluated the retention and survival of the early lifestages of common carp (*Cyprinus carpio*), rainbow smelt (*Osmerus mordax*), white sucker (*Catostomus commersoni*), striped bass (*Morone saxatilis*), and bluegill (*Lepomis macrochirus*) exposed to AFB fabric in the laboratory. Twelve flow-through testing apparati were used in a closed loop system to evaluate two flow rates (0.04 $L \cdot min^{-1} \cdot cm^{-2}$ [10 gpm/ft^2]) and 0.08 $L \cdot min^{-1} \cdot cm^{-2}$ [20 gpm/ft^2]) and three sizes of fabric perforation (0.5, 1.0 and 1.5 mm) with each species. ANOVA results indicate that, with one exception (pair wise comparison of bluegill survival between 1.0 mm and 1.5 mm perforations; $p = 0.0481$), survival of organisms was not significantly correlated ($p \leq 0.05$) to either flow rate or perforation size. Retention of organisms appeared to decrease significantly with increasing flow rate for one species of fish (pair wise comparison of rainbow smelt between 0.04 and 0.08 $L \cdot min^{-1} \cdot cm^{-2}$; $p = 0.0084$). In addition, increasing perforation sizes appeared to significantly decrease retention of three species of fish tested (common carp, rainbow smelt, and striped bass; with each increase in perforation size; $p \leq 0.05$), which potentially limits the effectiveness of larger perforation sizes in protecting the earliest lifestages of these species. Additional studies are planned for Spring of 2003 and the preliminary results from these may also be available for inclusion.

The Retrograde Monte Carlo Method – A Novel Computer Model of Aquatic Entrainment

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Dr. Johan Carlsson is a member of the technical staff at Tech-X Corporation in Boulder, Colorado. Dr. Carlsson got his Ph.D. in fusion plasma physics from the Royal Institute of Technology in Sweden. He worked on plasma physics and stochastic numerics for 3 years at the Oak Ridge National Laboratory. He then joined Tech-X Corporation where he is doing research and software development funded by the Department of Energy. His research interests include the application of stochastic numerics to the dynamics and entrainment of aquatic organisms.

ABSTRACT

Currently existing computer models of aquatic entrainment are far from optimal. We will introduce a new approach, the retrograde Monte Carlo method, that could be used for efficient, high-fidelity simulations of aquatic entrainment even for complicated geometries. Proposed intake structures and screening systems could thus be evaluated by computer simulations before being tested in situ. Computer modeling of aquatic entrainment requires the solution of two separate problems: calculating the background water flow and simulating the motion of the aquatic organisms, respectively. The retrograde Monte Carlo method is a better way to solve the latter problem. The traditional way of modeling the motion of the aquatic organisms would be to smooth them out into a density function governed by an advection-diffusion equation. Discretization in time and space converts the differential equation into a system of algebraic equations that can be solved using some standard technique such as Gaussian elimination. This approach has two disadvantages: it only allows for very simplistic motion of the aquatic organisms and it always produces a wasteful, global solution, i.e. the density function must be calculated everywhere even if only the entrainment rate at a single intake is of interest. A more direct way of modeling the motion of the aquatic organisms is provided by the conventional Monte Carlo (or Random Walk) method. In the Monte Carlo method a set of markers, each representing some known number of real aquatic organisms, is launched according to some initial condition. The markers are then advanced in time by periodically adding Monte Carlo kicks. The Monte Carlo random walk of the markers is a time-discretized approximation of the real motion. The sought solution, the entrainment rate at the intake, is then simply given by the rate at which the markers enter the intake. The fatal flaw of the conventional Monte Carlo is the fact that only very few of the markers find their way to the intake and contribute to the solution. The retrograde Monte Carlo method avoids this problem by launching the markers at the intake and pushing them backward in time. Markers that pass through a region where the initial condition was non-zero contribute to the solution. Because a much larger fraction of the markers contribute, the statistical noisiness of the solution is dramatically reduced. We will present simulation results (from a simple, model entrainment problem) that demonstrate the superiority of the retrograde method.

Innovative Design and New Technologies for Offshore & Onshore Cooling Water Intake Systems Aimed at the Preservation of Aquatic Life

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(Not submitted)

ABSTRACT
The Elmosa offshore-onshore intake systems are different in design and performance from the open-channel seawater intake systems. The Elmosa offshore onshore intake system consists of two main parts:

- The offshore portion includes
    - the InvisiHead - an omni directional 360 degree passive intake head system,
    - and the submarine pipeline-the flow delivery duct system
- The onshore portion includes the NatSep separation basin at which debris are separated and removed.

The patented InvisiHead uses a natural approach in dealing with problems usually associated with water intake systems. Potential flow and gravity are the main forces driving water into the systems. The major sources of intake troubles are Zebra Mussels, fish and fish larvae, seaweed, sand, trash, and oil spills. In the open channel intake systems these contaminants find their way into the intake channels where massive screening measures have to take place to filter these contaminants out. We utilize the powers of Mother Nature to drastically reduce any adverse impact caused by these sources of problems totally eliminating any possibility of oil flowing through into the intake system and jeopardizing the operation of the seawater users. The patented InvisiHead becomes hydraulically invisible to them, thus maximum protection is achieved and preservation of marine life is accomplished. The patented NatSep basin activates gravity to drive the flow in and separate sediments and debris from the water. The NatSep can be used also in the process of oil/water separation. This paper presents a new concept for an offshore and onshore seawater intake system with a uniquely engineered intake head to drastically reduce the inflow of seaweed, fish and larvae, and to keep zebra mussels from blocking the flow pathways and oil slicks from entraining into the raw water systems at exceptionally low initial costs especially that the system is self operating and self cleaning.

Using Large, Passive Suction Strainers to Reduce Water Approach Velocities of Intake Systems

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Mr. Gordon Hart works as a mechanical engineering consultant, having spent 25 years in energy and energy conservation industries. His background is in the thermal sciences. His career has included working first at Owens-Corning's Science & Technology Center and at Performance Contracting Group in a number of different areas including technical support, market & product development, and quality assurance. He has authored numerous technical papers and has a number of patents. One patented invention is a safety device for nuclear power plants; he helped design and fabricate these for fifteen US power plants while at PCG. Mr. Hart is an active member of ASTM C16 on Thermal Insulation, ASHRAE's Mechanical Insulation Systems Committee, and the National Insulation Association's Technical Information Committee. Mr. Hart earned a Bachelors of Science in Engineering from Princeton University and a Master of Science in Engineering from Purdue University. He is a Registered Professional Engineer.

ABSTRACT
With the recent release of standards for Rule 316(b) of the Clean Water Act by the US Environmental Protection Agency, designers of new industrial facilities will need practical and economical approaches to meet that regulation. One of the EPA's recommended approaches is to reduce the water velocity through the intake screens. Current intake structures typically have a water screen approach velocity of 2 to 2 ½ feet per second (fps) on average meaning some areas of the intake structure have local approach velocities that are greater than 2 ½ fps. One EPA recommended approach to addressing Rule 316(b) is to reduce the through-screen velocity to less than 0.5 fps (equivalent to an approach velocity less than about 0.2 fps). To meet both the spirit and intent of this approach, intake screens should not only achieve an average through-screen velocity equal to or less than 0.5 fps, but it should not exceed a local velocity of 0.5 fps at any point within the intake

screens. This paper proposes to comply with Rule 316(b) by installing large, passive suction strainers, onto the intake pipes, that are sized to limit the through-screen velocity to 0.5 fps at all points of the screen. These strainers would be a modification of a strainer concept originally designed and installed at a number of Boiling Water Reactor nuclear power plants in the late 1990's. Their role was to enable the Emergency Core Cooling System (ECCS) suction pumps to continue long term operation, following a nuclear accident, while filtering out large quantities of debris and yet limiting pressure loss across the debris to a low value. To verify the strainer concepts' performance, a series of tests were performed at a hydraulic laboratory. For cooling water intakes, these strainers would be much larger and constructed in box shaped modules. The exterior surfaces would consist of mesh screening. The interior would have a suction flow control device consisting of a large core tube pipe with holes. The core tube holes would be designed and sized to provide uniform flow over the length of the core tube. This, in turn, would provide uniform water velocities over the surface of the strainer. With this modular design, additional strainers could be added in series, connecting to one another with flanges. The main constraint for the design engineer would be to size all the holes based on their relative position to the intake pipe and to properly select pumps of adequate flow and suction head. The paper addresses some typical strainer system designs for water intakes and estimated costs of fabrication. With this information, the paper shows that this proposed approach to addressing EPA Rule 316(b) can be both practical and cost effective.

Environmental and Engineering Considerations for the Use of Aquatic Filter Barrier Technology to Prevent Entrainment of Planktonic Organisms into Electric Generating Station Cooling Water Systems

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Mr. Andrew McCusker earned a Bachelor of Arts in Biological Science/Chemistry and a Masters of Science in Zoology/Marine Ecology. Mr. McCusker has conducted and directed studies, monitoring projects and impact assessments for 30 years. For over 20 years Mr. McCusker has focused efforts on marine or estuarine environmental impacts, extensively with cooling water system intake and discharges. Mr. McCusker has worked with Gunderboom, Inc. since 1998. During that time he has participated in assessment, design, deployment and performance evaluations related to over 40 different sites or applications, on projects throughout the country, including power plants, reservoirs, beaches and dredging. He has managed projects for major utilities, petroleum companies and many Fortune 100 companies. Mr. McCusker leads company efforts in environmental regulatory and permitting aspects of projects and has overall responsibility for technical aspects of system evaluation and performance. Mr. McCusker recently served a two-year term as president of the National Association of Environmental Professionals.

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Since 1995, Mr. Dreyer has served as President and lead technical designer at Gunderboom, Inc. Actively involved in the marine, environmental and communications industries for 30 years working both in the private and government sectors, he brings solid experience to each unique solution. Mr. Dreyer's career has focused on design, fabrication, problem solution and operations in the marine environment. His career started with civil project construction, submarine installations, vessel modifications and repair, security projects, docks, dredging,

site development, survey and electrical installations for the Woods Hole Oceanographic Institute and peripheral support contractors. He has performed tasks for the U.S. Navy, Coast Guard, NOAA, Corps of Engineers, National Marine Fisheries and other similar organizations. Mr. Dreyer was founder, president and CEO of Underwater Construction, Inc., an Alaska-based marine contracting firm that undertook numerous projects in marine contracting, commercial diving, marine fabrication, salvage & emergency response and environmental contracting over an 18-year period. At Gunderboom, Inc., Mr. Dreyer has conducted or led virtually all of its projects since the company was formed in 1995. He is also a published author on technical topics and a recognized presenter at symposiums and conferences

ABSTRACT

Recent regulatory decisions have been made in New York that resulted in the approval by the State Board on Electric Generation that new generating facilities incorporate an aquatic filter barrier. The Gunderboom Marine Life Exclusion System™ (MLES™) is a filter barrier that prevents fish eggs and larvae from being entrained in the cooling water to the plants. Filter barrier technology has also been specifically identified both in the recently-issued USEPA final regulations for cooling water system technology for new facilities and in the Proposed Rule for Existing Facilities as a viable means of achieving required minimization or reduction of impacts of a cooling water intake structure (CWIS). Not all facilities are candidates for effective use of the technology. The best technology available (BTA) to mitigate environmental impacts of CWIS's is influenced by a number site-specific variables, including water withdrawal volume, intake configuration, facility operation, source water characteristics, and economic considerations. These work alone or in concert. The factors that are important to the feasibility and design of an aquatic filter barrier are the following: target species or organisms for exclusion and their seasonality, water depths and bathymetry, water level fluctuation, currents and wave conditions, presence and degree of debris, ice, suspended solids, and location relative to shipping or other maritime uses of the nearby waters. To address these many environmental, regulatory and operational variables, engineers designing Gunderboom filter barrier systems have a number of design factors that can be varied. First, there is a choice of filter fabrics and the density of the fabric and the size of the perforations. Secondly, there is a range of physical designs for deploying the filter fabric material, including, an anchored floating filter barrier, a filter barrier secured to fixed pilings or sheet pile cells, a solid subtidal structure, bulkhead-mounted fixed frame panels, and cartridges. Configuration may be varied to include an accordion-like structure to increase filter area. An intake pipe or series of intakes may be buried under river or ocean floor and surface within an aquatic filter barrier-enclosed structure. This paper will present and explain the various factors affecting design and will review the various design approaches to address these considerations. It will conclude with an assessment of the range of applications and the probable approach and potential applicability of filter barrier technology to those applications.

Belle River Power Plant Angled Intake Structure

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ABSTRACT
The Belle River Power Plant is a 1260 MW, two-unit, once-through cooled facility located on the St. Clair River approximately 46 mi. north of Detroit, MI. The design of the intake structure incorporates several important features for reducing the entrapment potential for fish. The intake structure, both trash racks and traveling screens, are angled 20 degrees into the river flow to guide fish away from the plant's intake. The trash racks and traveling screens are also mounted flush with the support structures to eliminate embayments that are attractive to fish. Other features include a lateral escape way for fish in front of the traveling screens and low intake approach velocities. The plant minimizes the use of cooling water on a year round basis in order to optimize turbine cycle performance. Based on a one year impingement study, the total number of fish impinged was considerably less than what one would expect for this size facility located on this water body. Also, most of the impinged fish were less than 3.9 in (100 mm) in length, indicating a possible reduced susceptibility of larger fish to impingement on the traveling screens.

Determination of Hydraulic Zone of Influence using 3-D Modeling Techniques

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Dr. John Richardson is a Senior Fluids Engineer at the Alden Research Laboratory (Alden) located in Holden, Massachusetts. Dr. Richardson received his B.S. in Mechanical Engineering from Lafayette College in Pennsylvania and his M.S. and Ph.D. in Civil Engineering from the University of Maine. After completing his schooling, He contributed to the development of the ***FLOW-3D*** CFD software system while working for Flow Science now located in Santa Fe, New Mexico. He then became a Program Manager for Earth Tech located in Concord, New Hampshire. For the past 3 years he has worked for Alden. His main research interests involve the numerical modeling of free surface flows, the design of hydraulic structures, and the development of innovative strategies for offshore aquaculture systems.

Abstract

The natural hydrology of the water body, and its relationship to plant hydraulics, is a key factor in evaluating the potential of a CWIS to impinge and entrain aquatic organisms. For an organism to become entrained, it must occur in the hydraulic zone of influence (HZI) of an intake. The probability that an organism will enter this area is controlled by complex hydrologic processes that extend into the far field and are influenced by a variety of other factors. Thus, while the proximity of a primary spawning and/or nursery area to a CWIS can be an important influence on the fraction of population potentially entrained for any individual species, other factors interact with proximity to determine actual susceptibility to entrainment. Extensive field data collection efforts can be used to identify the HZI, however, collecting data for a range of flow conditions is both time consuming and costly. The use of computational fluid dynamics (CFD) offers a state-of-the-art means for identifying the HZI using numerical models in a cost-effective manner. The primary advantages of using CFD is that variable flow conditions can be evaluated to determine the HZI under different plant and water body flow rates, as well as tidal and weather conditions. The capabilities of four modeling systems in defining the HZI at six CWIS on various water body types (i.e., reservoir, river, tidal river, estuary, Great Lake, and coastal CWIS) were evaluated: MIKE21, MIKE3, Fluent, and FLOW3D. Appropriate models for each water body type can probabilistically determine the fate of particles released from any given location within the flow field. Maps were created to probabilistically define the HZI, *i.e.* what is the probability that a non-motile, organism released from a given point in the flow field will be entrained by the cooling water intake. Graphic results of model studies will be presented showing the computed HZI for each power plant. The type of water body and flow conditions for which each model was best suited will be discussed. In addition, specific model limitations and suggestions will be discussed. Understanding and characterizing the HZI will be key to establishing power plant baseline impingement and entrainment impacts.

A Comparison of Young-of-the-Year Fish Impingement on 3/8” x 3/8” Mesh Traveling Screens with 3/16” x 1” Mesh Traveling Screens

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Biosketch

Mr. Paul Sawyko is currently an Environmental Quality Coordinator within the Fossil / Hydro Electric Generation Area of Rochester Gas and Electric Corporation (RG&E) in Rochester, New York. Mr. Sawyko received his B.A. in Biology from Canisius College in Buffalo, NY and his M.S. in Marine Science from the C.W. Post College of Long Island University. He has spent the past 30 years with RG&E focused upon the water resources area, including water quality / discharge permits (SPDES) and aquatic monitoring studies in support of SPDES thermal variances and intake system operation (Sections 316 (a) & (b) of the Clean Water Act, respectively). He has prepared both 316 (a) & (b) Demonstrations, and has been instrumental in achieving nearly 30 years of continuous impingement monitoring at RG&E's Ginna Nuclear Station and Russell Station, both located on Lake Ontario. During 19 years of his career at RG&E, Mr. Sawyko established and directed the RG&E Environmental Laboratory to perform regulatory monitoring and reporting in areas of aquatic biology and water quality. Mr. Sawyko has also been involved in numerous R&D Projects, most notably concerning the impacts of zebra mussels upon power plant operations, and has developed effective zebra mussel treatment control programs for power plant service water systems utilizing chlorine. Most recently, he served as overall lead for the preparation of an Environmental Report in support of the Ginna Nuclear Power Station License Renewal Application to the Nuclear Regulatory Commission.

Abstract

The original traveling screens were of the traditional design, consisting of woven wire mesh with 3/8 in. square openings. The screen replacement a project was initiated to replace the original screening material with a new stainless steel screening material which has a mesh of 3/16 in. x 1 in. and a crimped fit construction resulting in an overall smoother surface texture. One of the four traveling screens was completely replaced with the new

screening material during 2000, and each subsequent year another screen has been replaced with the new material, resulting in three of the four screens being deployed with new screens by the fall of 2002.

During this period of screen replacement, impingement studies were conducted which differentiated between collections from each screen type (i.e., new or old). These studies were designed to provide information which can be used to (1) overall relate impingement findings from the old screens to the new screens, and (2) investigate the relative impingement of smaller (typically young-of-the-year) fish by each screen mesh, thus determining the number of such individuals subject to the impacts of further entrainment. This analysis focuses upon the second of these two assessments, and is based upon information obtained from seven species collected during the study periods: alewife (*Alosa psuedoharengus*), rainbow smelt (*Osmerus mordax*), emerald shiner (*Notropis atherinoides*), spottail shiner (*Notropis hudsonius*), threespine stickleback (*Gasterosteus aculeatus),* yellow perch (*Perca flavescens*), slimy sculpin (*Cottus cognatus*). For five of these species (alewife, emerald shiner, spottail shiner, yellow perch, and slimy sculpin) a shift in length frequency distribution towards smaller sizes was apparent for the new screening. For one species, rainbow smelt, a length frequency distribution shift towards larger size was found for the new screening. Finally, screen type did not appear to effect length frequency distribution of threespine stickleback.

Effectiveness of 316(b) BTA at the Water Intake for a Midwestern Paper Mill

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BIOSKETCH

Mr. Greg Seegert is EA's Chief Aquatic Ecologist and has managed EA's Deerfield, Illinois office for 21 years. He is a senior biologist with nearly 30 years of experience who has worked with utilities, as well as other industries and regulatory agencies, throughout his career. His areas of special expertise are aquatic toxicology and aquatic ecology. Mr. Seegert has conducted studies throughout the Midwest and much of the East and Southeast. He is currently directing 316(b) studies on the Mississippi River, the Upper Illinois Waterway and Lake Michigan. He is a recognized expert on the theory and application of multi-metric community level assessment techniques. He has extensive experience in the design of biological sampling programs to assess impacts to aquatic life and evaluating the impacts of the withdrawal of water for cooling purposes on aquatic communities. Mr. Seegert has a BS and MS in zoology from the University of Wisconsin-Milwaukee.

ABSTRACT

From March 1985 through April 1987, EA conducted fish studies to support a 316(b) demonstration for a paper mill located on the Menominee River in Michigan. The intake has a design capacity of 42 cfs, but normal operation requires only 26 cfs. Through-screen velocity is ≤0.5 ft/sec. The traveling screens are fine mesh, with a slot openings of 0.1 inch. Low impact backwashing returns impinged fish to the river. The mill's NPDES permit required that studies be conducted for at least one full year, and that annual loss estimates be developed for larval, juvenile, and adult fish. The permit required that the 90% confidence interval around these losses could not exceed ±10% of the estimates. Prior to starting the study, we constructed hypothetical data sets, then used power analysis to determine how many samples would need to be collected to achieve the necessary precision.

The study had five major elements: adult fish monitoring, larval fish monitoring, entrainment collections, impingement collections, and population studies. Studies were done pre-operationally in 1985 and post-operationally in 1986-87. The pre- and post-operational adult fish studies resulted in the collection of more than 18,000 fish representing 33 species.

The in-river larval fish studies consisted of collecting about 600 samples each year during the spring and summer. Rock bass and smallmouth bass, which were abundant in the adult fish collections, were rare in the

larval collections, indicating that adult fish data alone may be insufficient to predict entrainment risks. Impingement rates were low. Collections on 82 dates yielded only 337 fish. In terms of composition, the impingement catch was distinct from all other phases of the study. For example, white sucker, one of the most abundant species in the river, was represented by only nine individuals. Survival studies indicated that the intake's fish return system was operating effectively as about 90 percent of all fish impinged were returned to the river alive. Entrainment samples were collected on 62 dates from late April through early August 1986. Each of the samples was collected throughout a 24-hour period. The 62 collections yielded a total of nearly 14,000 larvae. From May through October 1986, adult white sucker, smallmouth bass, rock bass, walleye, and northern pike were marked and their populations estimated based on the number of marked fish recaptured.

Based on the numbers of fish entrained or impinged compared to the size of the at risk populations, we concluded that impacts to source waterbody fish communities would be minimal (i.e., there would not be an adverse environmental impact). Michigan DNR concurred with this assessment and no additional mitigative measures or design modifications were ever required for the mill.

Seabrook Station Offshore Cooling Water Intake System

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Mr. Ron Sher is an Environmental Scientist at FPL Energy Seabrook Station in Seabrook, New Hampshire. Mr. Sher is responsible for coordinating NPDES Permit Compliance activities such as the plant's extensive Environmental Monitoring Program. Mr. Sher received his B.A. in Zoology from the University of New Hampshire.

ABSTRACT

The Seabrook Station Nuclear Plant employs a submerged offshore cooling water intake structure (CWIS) design. This design was the original CWIS in operation when the power plant began generating electricity in 1990. This CWIS has resulted in lower impingement and entrainment impacts than those associated with shoreline intake structures.

Seabrook Station is a single-unit 1,160 megawatt nuclear plant in Seabrook, New Hampshire. The plant is located about two miles inland from the Atlantic Ocean. The plant's Cooling Water System employs a once-through submerged offshore ocean intake structure and discharge diffuser design. Between the power plant and the ocean is a saltwater estuary, harbor and barrier beach. The Cooling Water System was designed to avoid impact to this adjacent estuarine environment by installing deep underground cooling water tunnels to draw cooling water from and return it to the waters of the Atlantic Ocean. Nineteen-foot diameter intake and discharge tunnels extend about 7,000 and 5,500 feet offshore, respectively, to the intake and discharge location. Each tunnel is located in bedrock, about two hundred feet below sea level.

The Cooling Water System provides an average flow of about 580 million gallons per day of ocean cooling water. The ocean cooling water is drawn into three offshore intake structures that are located bout 7,000 feet offshore and in water about 60 feet deep.

The three CWIS velocity intake caps are 30 feet in diameter with seven-foot tall horizontal openings and draw ocean water in at a relatively low speed of about 0.5 feet per second. The intakes were originally, designed with vertical bars spaced 16 inches apart to prevent large debris from entering the intakes. In 1999 additional barrier panels were installed on the offshore intakes to reduce the spacing to about 5 inches to prevent the entrapment of seals. The installation of the barrier panels necessitated an increase in the frequency of the removal of biofouling organisms that grow on the intake structures. Since the barriers were installed fish

impingement has been reduced. This decrease is likely the result of the removal of fouling material, which may have provided habitat to fish.

The operation of Seabrook Station has not impacted the balanced population of marine organisms near the power plant. This conclusion is based on an extensive ongoing environmental monitoring program that includes 12 years of monitoring since that plant went into operation in 1990 and dates back to the early 1970's during the initial permitting for the power plant.

Seabrook Station's NPDES Permit was renewed in April 2002. The Environmental Protection Agency stated in the renewed permit that it "has determined that the Cooling Water Intake System, as presently designed, employs the best technology available for minimizing adverse environmental impact." The EPA went on to state that "the present design shall be reviewed for conformity to regulations pursuant to Section 316(b) when such are promulgated."

Interpretation of Recent Measurements of the Efficiency of an Acoustic Fish Deterrent System

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Dr. Andy Turnpenny is a fish biologist and is currently Managing Director of Fawley Aquatic Research Laboratories and Fisheries Director of Fish Guidance Systems Ltd, both located in Southampton England. Andy spent 15 years as an environmental research scientist with the UK power industry and was formerly head of aquatic research for National Power PLC. He has specialized in fish entrainment and fish screening and passage issues.

ABSTRACT
Electrabel operate a Fish Guidance Systems infrasonic fish guidance system to keep fish out of the cooling water intake of the Nuclear Power Station at Doel in Belgium. The power station draws cooling water from the Schelde tidal estuary, and the system, installed in 1997, is on the off-shore intake for Reactors 3 & 4 which are each of 2,000 MW. The system has been evaluated for efficiency over several years by Leuven University, and the efficiency varies from 21 % for flat fish up to 98 % for herring, the target species.

The reason for these differences appears to lie in the differing hearing sensitivities of the different species, and hence the levels at which they will react to a sound stimulus. The results are addressed in the dB_{ht}(*Species*) scale, which enables fish behavior to sound stimuli to be related to objective and biologically meaningful

measurements of sound level. The results when analyzed this way indicate a criterion that a level of sound about 90 dB above threshold within the species' frequency passband is required to cause efficient deflection.

The significance of this is discussed in the context of mixing fish screening and return technologies to achieve the greatest environmental benefit within a fixed budget.

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